

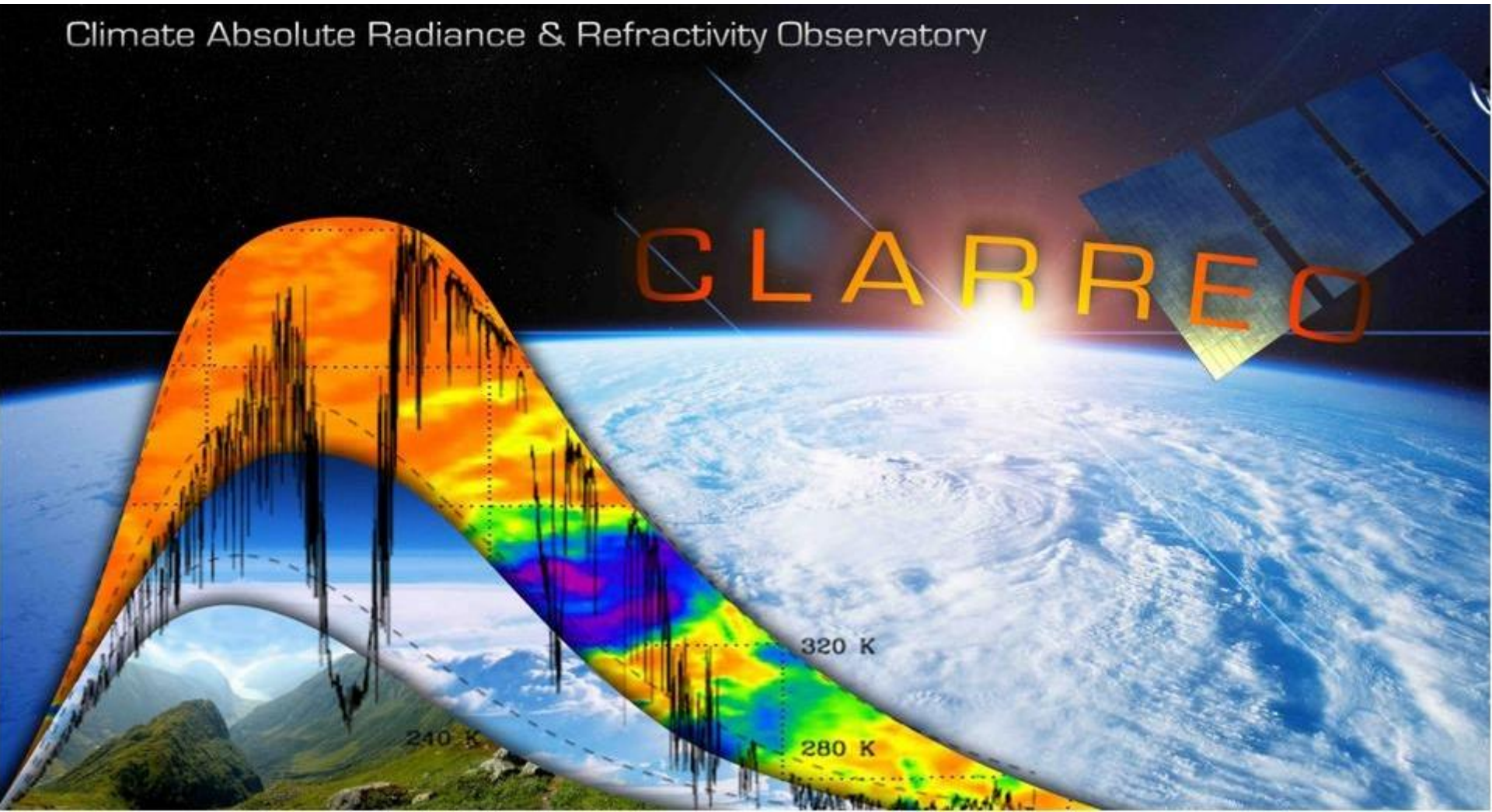


GODDARD SPACE FLIGHT CENTER

# CLARREO ISS Pathfinder

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Climate Absolute Radiance & Refractivity Observatory

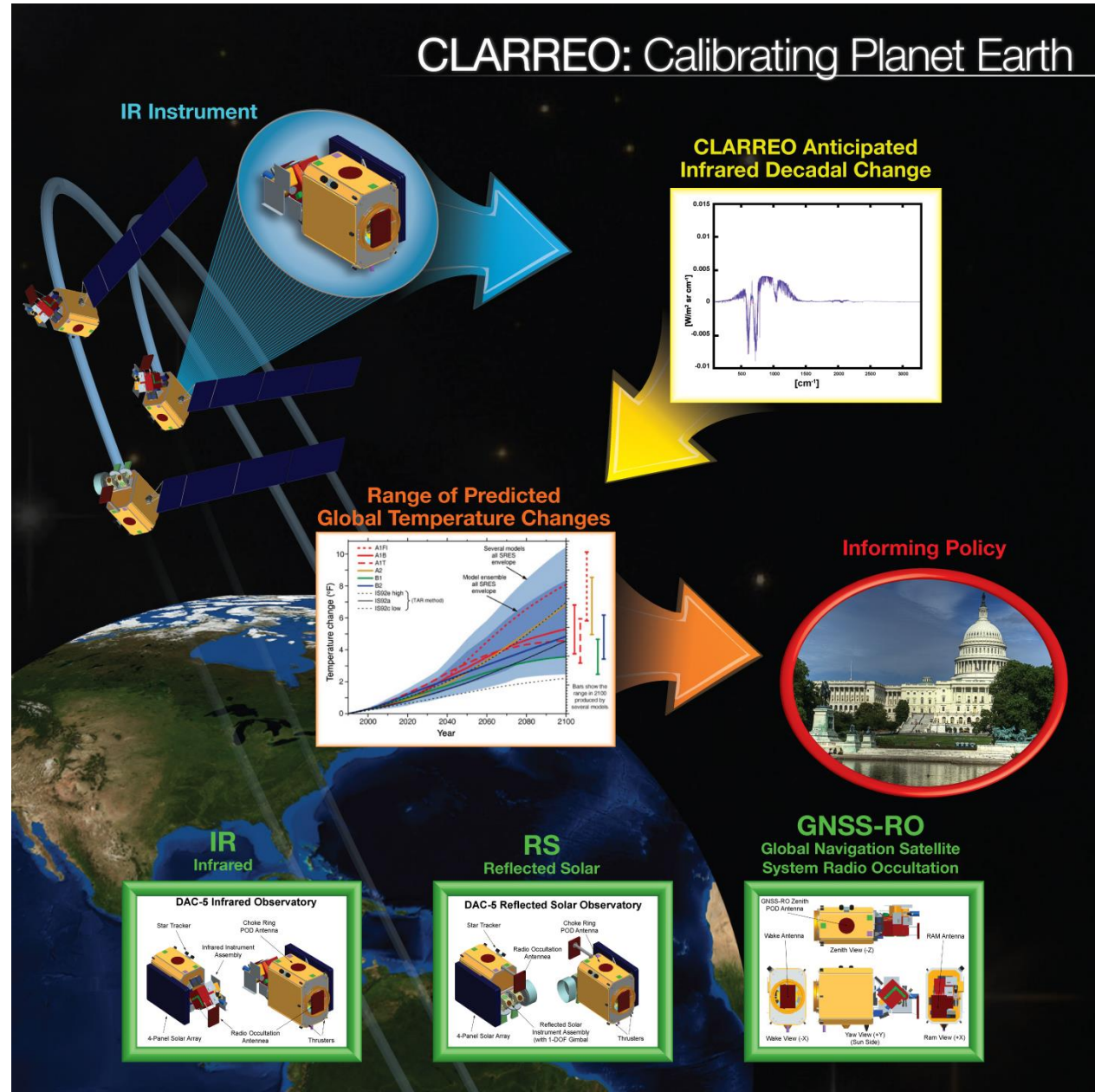


# CLARREO Solves the Climate Accuracy Challenge

- Climate Absolute Radiance & Refractivity Observatory
- Insufficient absolute accuracy remains an Achilles Heel for climate change observations
  - Improved accuracy needed for
  - Climate model testing
  - Climate model predictions of future change
  - Societal policy decisions



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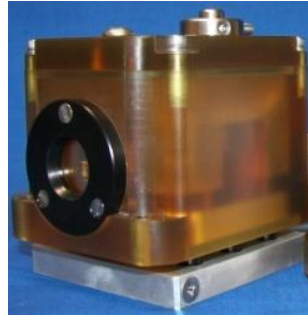
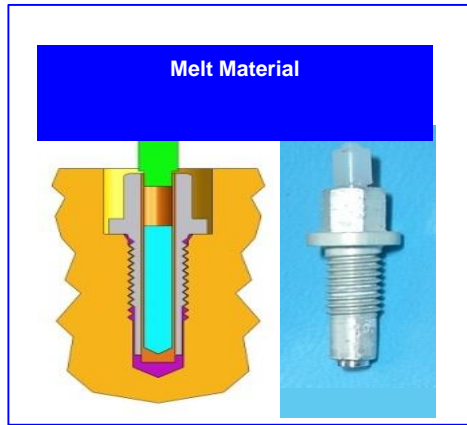




# CLARREO Solves the Climate Accuracy Challenge

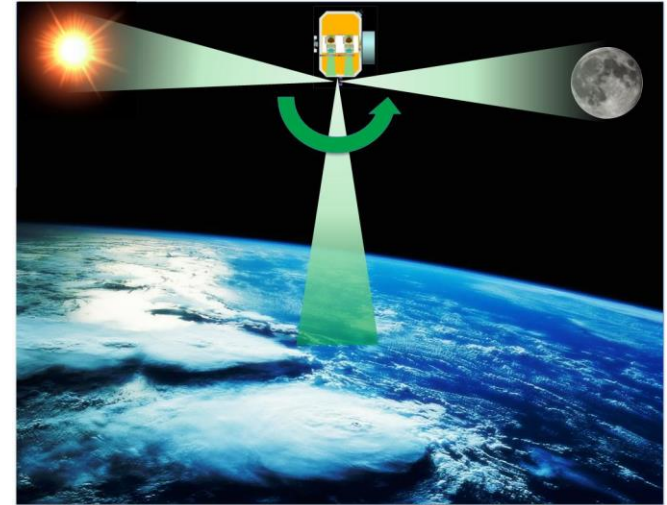
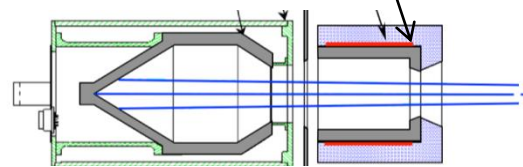
Gaps in record would not degrade climate records

Phase Change Cells



Quantum Cascade Laser (QCL)

Heated Baffle

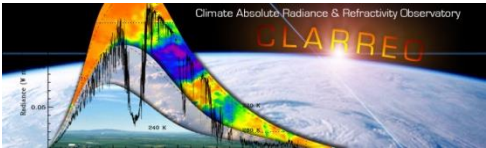
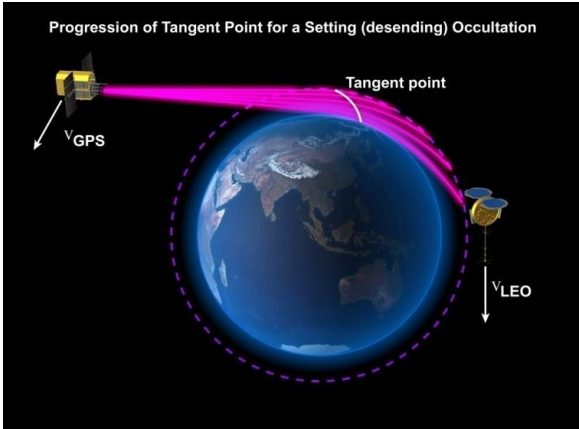
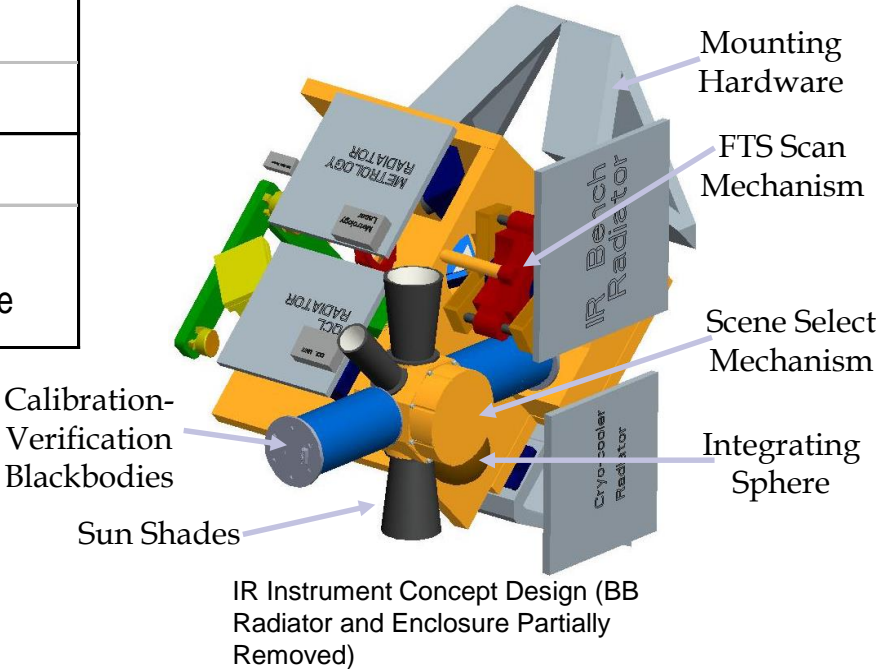
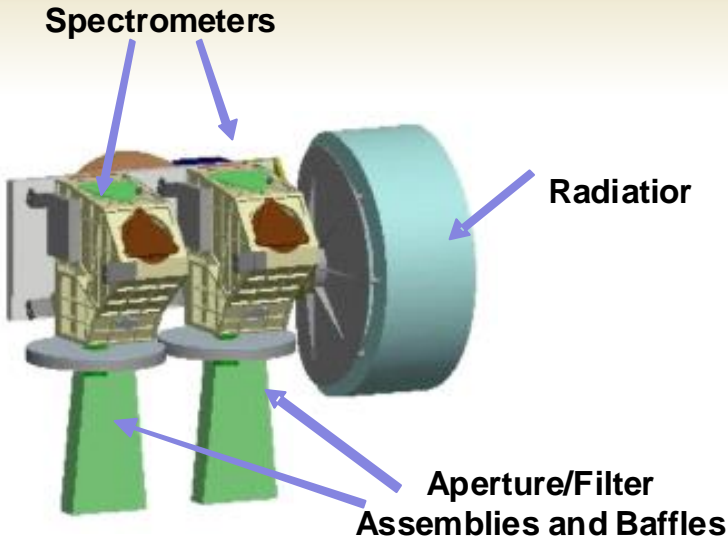


- Accuracy requirements provide observations to allow climate change detection within 20% of perfect observations (0.1 K and 0.3% of reflectance  $k=2$ )
- CLARREO provides SI traceable high accuracy rigorous measurements of the entire solar and infrared spectrum ("NIST in orbit") to detect long-term climate change trends
  - Approaches based on work of academia, government, and industry
  - Will not require overlapping data records

# CLARREO summary

## Payload Suite

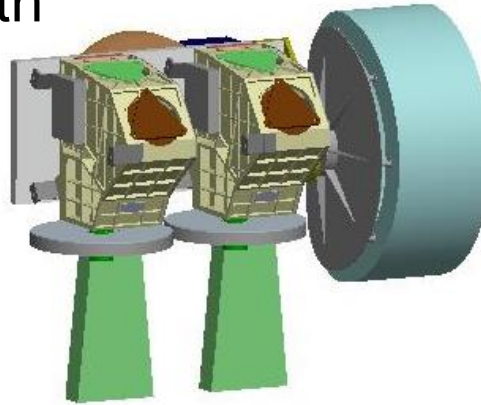
Instrument	Features	
Infrared Spectrometer	Type	Fourier transform spectrometer
	Spectral Range	5 to 50 micron
	Configuration	Single combined instrument
Reflected Solar Spectrometer	Type	Grating spectrometer
	Spectral Range	320-2300 nanometer
	Configuration	Two box design
GNSS Radio Occultation System	Signal Range	GPS and Galileo
	Configuration	Receiver Two occultation antennae



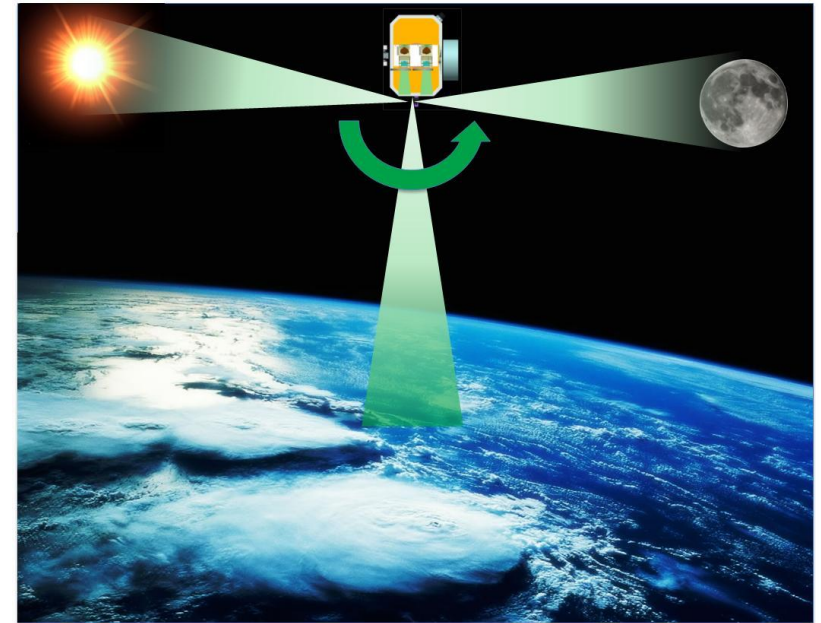
# RS Instrument

Offner system covering 320 to 2300 nm with 500-m GIFOV and 100-km swath width

Reflectance traceable to SI standards at an absolute uncertainty  $<0.3\%$

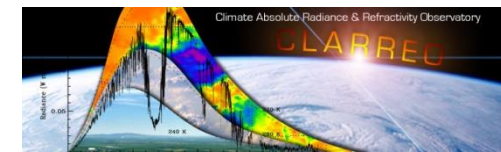
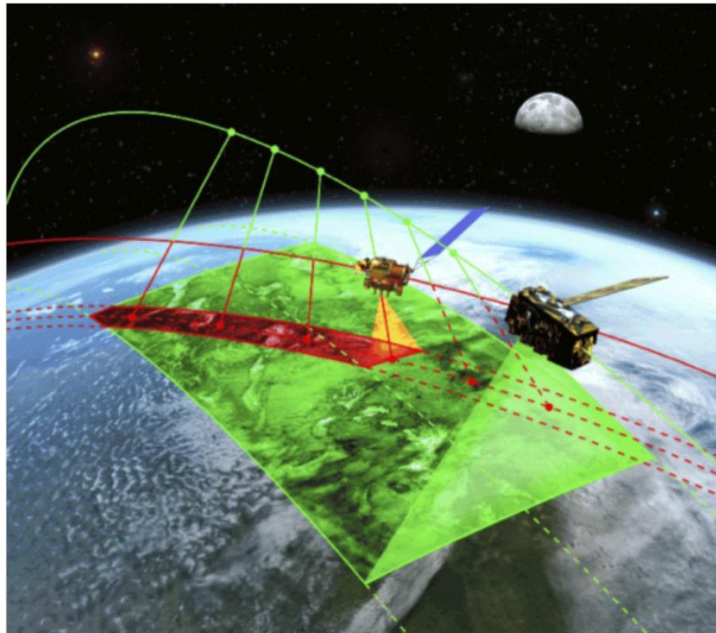


**Benchmark reflectance** from ratio of earth view to measurements of irradiance while viewing the sun



Lunar data provide calibration verification

Intracalibration plays a key role in developing climate record





# CLARREO Project update

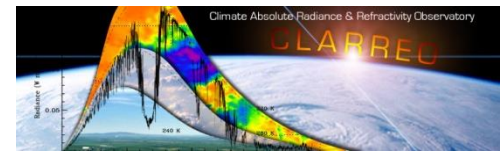
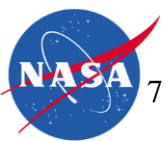
## CLARREO continues in extended pre-phase A with a launch date after 2020

- 2010 - CLARREO passed MCR with no major RFAs and recommended to proceed to Phase A
- 2011 – Budget reductions placed CLARREO into extended pre-phase A
- 2012 – Results on economic value of CLARREO climate science to society: between \$3T and \$20T (2012 U.S.)
- 2013 – CLARREO presented ISS concept to NASA HQ achieving 73% of baseline mission science for ~35% of original cost
- 2014 – NASA HQ requested Technology Demonstration ideas for ISS
  - Multiple CLARREO groups submitted concepts for RS and IR
  - Revised budget phasing submitted at HQ request
- 2014 – CLARREO develops low cost free-flyer mission concepts
- **2015 – February. President's budget includes a CLARREO Pathfinder line to fly RS and IR on ISS with a 2019 launch**

# CLARREO Pathfinder

“The FY 2016 budget request fully funds ....., and technology demonstration instruments for risk reduction for CLARREO (for launch to the International Space Station (ISS) in 2019).”

“The 2007 National Academies Earth Science Decadal Survey recommended the Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission as a Tier 1 mission that would be a key component of the future climate observing system. The CLARREO Pathfinder mission will demonstrate essential measurement technologies; validate the high accuracy radiometry required for long-term climate studies in support of other Decadal Survey and land imaging missions; and initiate measurements that will benchmark the shortwave reflectance and infrared climate record. NASA plans to host the two CLARREO Pathfinder instruments, Reflected Solar (RS) and Infrared (IR) spectrometers, on the International Space Station in FY 2019.”



# Pathfinder objectives

This is a step towards the CLARREO mission

- Goal is to demonstrate essential measurement technologies of the CLARREO Tier 1 Decadal Survey mission
- Reduce risk and provide confidence that the full CLARREO could achieve the science goals
  - Focus on key elements for TRL advancement
  - Avoid mission creep
- Flying in a precessing orbit significantly enhances sampling for inter-calibration of existing sensors



# Pathfinder limitations

## Budget and orbital limitations limit what the CLARREO Pathfinder can do

- Pathfinder is not the CLARREO mission
- Cannot achieve global coverage with direct benchmark
- Class D approach can limit lifetime to below the five year requirement of CLARREO full mission
- ISS orbit conditions limit IR nadir collection to about 75% of total time on orbit
- Limitations have largest impact on achieving the highest accuracy science climate benchmark
- Much less impact on demonstrating extremely valuable technology development information related to the calibration and verification systems

# Pathfinder will provide valuable science

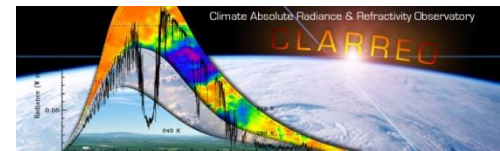
Tech Demo studies already give a good idea of what CLARREO Pathfinder could achieve

- First on-orbit SI traceable calibration methodologies to achieve accuracies 5 to 10x higher than current IR and RS instruments
- Identify possible design modifications for full mission
- Provide first observed far-infrared (IR) spectra since Nimbus 4 IRIS in 1971
- Provide intercalibration with LEO and GEO satellites that would provide climate benchmark data
- Put lunar spectral irradiance on an SI traceable scale with 10 to 20 times current accuracy

# CLARREO Pathfinder Budget

Official funding still awaits inclusion of Pathfinder in 2016 Congressional Appropriation

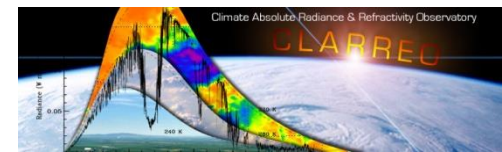
- Recent NASA budget process included a nominal five-year budget in the May 2105 NASA budget process
- Support the flight of two instruments, Reflected Solar (RS) and Infrared (IR) and spectrometers hosted on the International Space Station in FY 2019
  - \$15.0 M Request FY 2016
  - \$61.7 M Notional total for FY17 – FY 20
- Portion of above amounts are held at NASA HQ as reserve and not available for mission
- Other project reserve requirements means ~\$20M for each instrument





# CLARREO Pathfinder budget

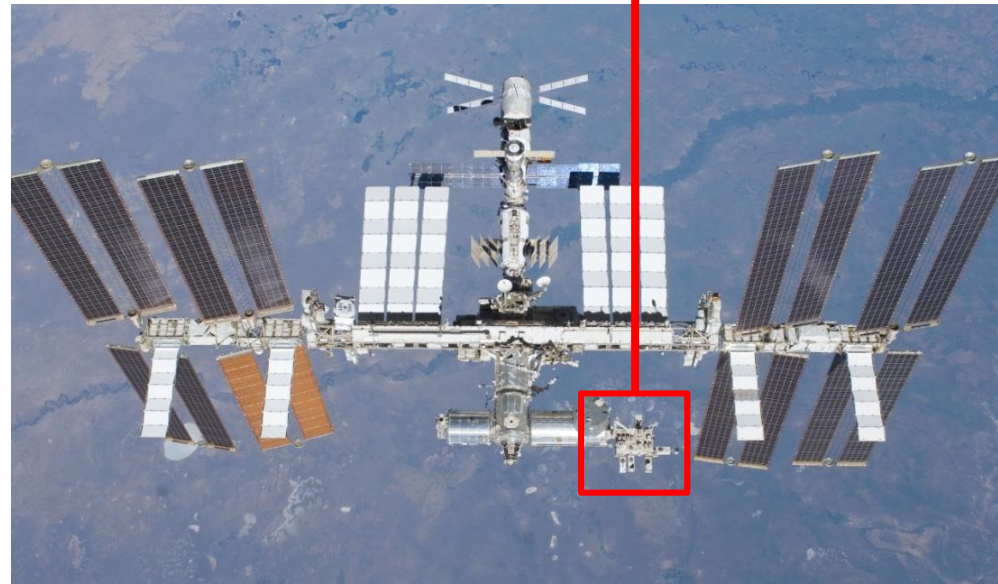
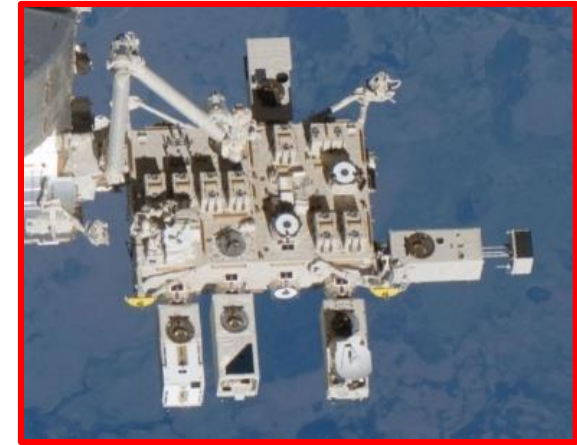
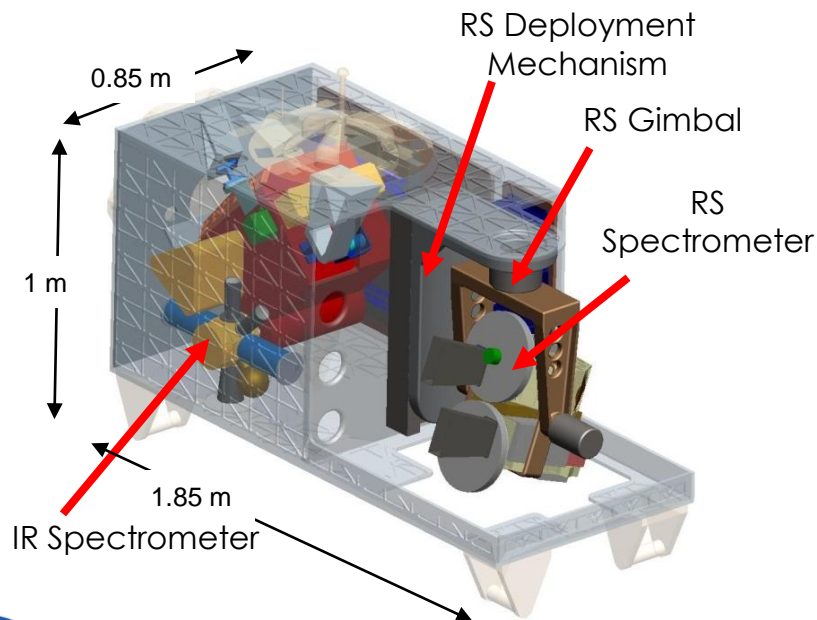
- CLARREO Pre-Formulation budget will fund portions of the in-house workforce from the existing Calibration Demonstration System budget lines
- Assumes work on existing CDS systems cease and the workforce redirected to the Pathfinder
- Operations concept is TBD – Instruments may operate independently
- HQ Guidance
  - Tailored Class D implementation approach
  - Science requirements can be adjusted to fit budget
  - Include both IR and RS instruments
  - ISS will provide location and accommodation issues guidance



# Can it be done?

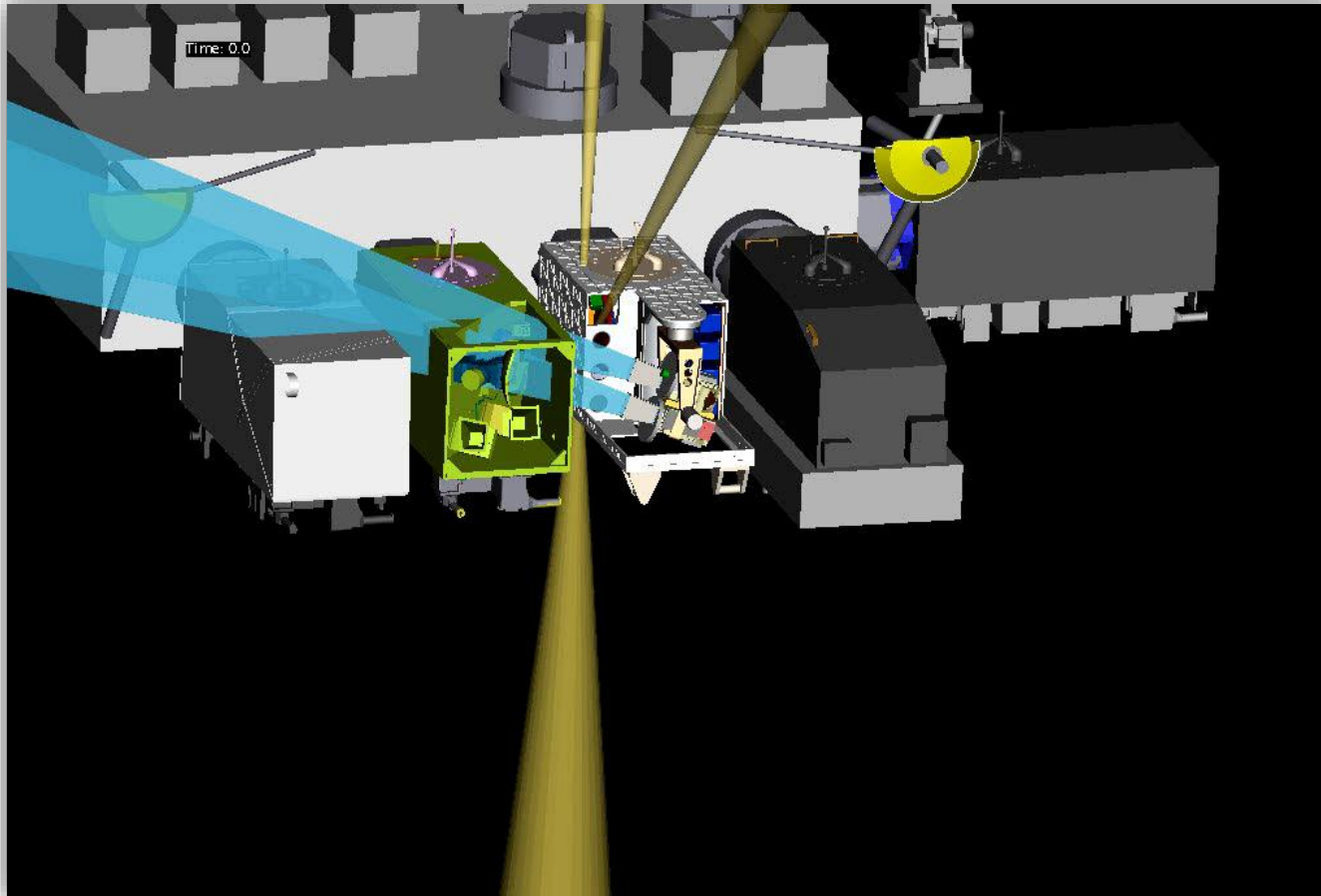
Budget is a challenge but pre-phase A work has been very productive

- ISS Tech Demo studies showed ISS is feasible from mass, power, data rate and volume
- Selected the Japanese Experiment Module Exposed Facility (JEM-EF) for maximizing viewing opportunities



# RS intercalibration example

Previous ISS studies also showed how operations could take place





# CLARREO Pathfinder – Parting comments

Pathfinder provides an equal array of challenges and opportunities

- Still awaits formal budget approval in 2016 Congressional budget
- Many difficult decisions still remain on how best to meet schedule and cost
- Lessons learned from implementing the Pathfinder will be invaluable to future CLARREO missions as well as other earth science missions
  - Laboratory calibration approaches
  - On orbit operations and improved calibration
  - Challenges of high-accuracy intercalibration
- CLARREO team is greatly excited for this potential opportunity and is looking forward to the challenge

